Carcass Fat-free Lean Gain of Chinese Growing-finishing Pigs Reared on Commercial Farms

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ABSTRACT : Five regions and 258 pigs were selected for this study: North (Beijing), Central (Wuhan), South (Guangzhou), Southwest (Chongqing), Northeast (Harbin). Five typical genetics of growing-finishing pig were selected: Landrace×Large White×Beijing Black, Duroc×Landrace×Large White, Duroc×Large White×Landrace, Landrace×Rongchang, Landrace×Harbin White, respectively at each sites. The basal diet was a corn-soybean meal containing sufficient nutrients to meet requirements. Carcass fat-free lean gain was determined by dissecting and analyzing chemical composition of the carcass. Cubic function fitted lean moistures to live weights better than other functions. Exponential function fitted lean lipids to live weights equally to allometric function. Carcass fat-free lean gain of Duroc×Large White×Landrace, Landrace×Large White×Beijing Black, Duroc×Landrace×Large White, Landrace×Harbin White, Landrace×Rongchang from 20 to 100 kg of average body weight was 259 g/d, 261 g/d, 311 g/d, 220 g/d, 200 g/d, respectively. All are lower than intermediate fat-free lean gain in NRC (1998). *(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 10 : 1489-1495)*

Key Words : Growing-Finishing Pigs, Fat-free Lean Gain, Genetics

INTRODUCTION

The inherent reason for different nutrient requirements of different genetically hogs is that protein (muscle) and fat are deposited at different rates. Increased information on body composition will form the basis for diet formulation. Basic knowledge of how modern commercial genotypes growing will be essential, as diet formulation becomes more precise, allowing for maximum carcass quality at the lowest possible cost (Lorschy et al., 1997b). The maximum protein accretion and associated carcass lean growth rate determine the pig's nutrient requirements for growth, composition of growth, and response to nutrition or management changes (Stranks et al., 1986; Campbell et al., 1988; Moughan, 1989; Schinckel, 1997; Lorschy et al., 1997a). Schinckel et al. (1996) thought we can use fat-free lean index data to estimate daily protein accretion rates needed as inputs for swine growth models. NRC (1998) illustrated the inherent relationship between the carcass fat-free lean gain and nutrient requirements in detail. Nutrient requirements can be predicated by carcass fat-free lean gain, average body weight, the ratio of barrows and gilts, temperature, and feeding stocking density. Body weight, ratio of barrows and gilts, temperature of pig's house and feeding stocking density are easy to be measured. However, Carcass fat-free lean weight is not fairly easy to be measured and most pig farmers have no distinct value concept about fat-free lean gain. Therefore, it is difficult for nutrient requirement

model of NRC to be applied in practice. Objectively, this requires that we know the value of carcass fat-free lean gain of growing-finishing pigs on commercial farms.

China is currently revising Feeding Standards of Chinese Swine. It will save a great deal of human resource, material resource, money and time if NRC model is incorporated because we can use it to evaluate the data of nutrient requirements. This experiment was conducted to determine carcass fat-free lean gain of growing-finishing pigs and predicated their main nutrient requirements using NRC (1998) model. The objective was to detect the veracity of predicted value, promote the application of NRC (1998) model, and offer a scientific basis for revising Feeding Standards of Chinese Swine.

MATERIALS AND METHODS

Experimental sites

Five districts were chosen for this study: North (Beijing), Central (Wuhan), South (Guangzhou), Southwest (Chongqing), and Northeast (Harbin).

Experimental design

North (Beijing) : The experiment was conducted on Beijing Changping Liu Village Pig Farm. 48 growing pigs of Landrace×Large White×Beijing Black at 19.0 kg of average body weight were selected. Males and females were divided into 12 pens (6 pens, barrows; 6 pens, gilts). 4 pigs per pen. The pig house was insulated from outside. Each pen is 1.8×1.5 square meter.

Central (Wuhan) : The experiment was conducted on

the Tanshan Pig Farm. Wuhan Hannan Livestock Company. 60 growing pigs of Duroc×Large White×Landrace at 20.1 kg of average body weight were selected. Male and female were divided into 12 pens (6 pens, barrows; 6 pens, gilts). 5 pigs per pen. The pig house was semi-insulated from outside. Each pen is 3.8×2.3 square meter.

South (Guangzhou) : The experiment was conducted on Yungan Pig Farm, Guangdong Wen's Foodstuff's Group Co. Ltd. 54 growing pigs of Duroc×Large White×Landrace at 19.9 kg of average body weight were selected. Male and female were divided into 6 pens (3 pens, barrows; 3 pens, gilts), 9 pigs per pen. The pig house was semi-insulated from outside. Each pen is 4.1×3.2 square meter.

Southwest (Chongqing) : The experiment was conducted on Experimental Pig Farm, Chongqing Academy of Swine Production Sciences. 48 growing pigs of Landrace× Rongchang at 19.1 kg of average body weight were divided into 6 pens (3 pens, barrows, 3 pens, gilts), 8 pigs per pen. The pig house was insulated from outside. Each pen is 3.8×2.4 square meter.

Northeast (Harbin) : The experiment was conducted on Heilongjiang Xiangfang Experimental Pig Farm, 48 growing pigs of Landrace×Harbin White at 21.4 kg of average body weight were divided into 6 pens (3 pens, barrows, 3 pens, gilts), 8 pigs per pen. The pig house was insulated from outside. Each pen is 3.0×2.5 square meter.

All houses of the pigs are concrete floor, drain contamination well, ventilate well. All diets were offered *ad libitum*, with drinking water. The other managements were done according to conventional methods. Experimental designs and feeding managements were clearly shown in Table 1.

Diets

All diets were corn-soybean meal diets, the premix was mixed identically and all formulas were uniform in order to guarantee experimental consistency. Mash diets were formulated to satisfy at least the nutrient requirements of

20-50 kg. 50-80 kg. 80-110 kg growing-finishing pigs in NRC (1998). Some nutrient levels are higher than that in NRC (1998). The feed samples were collected after the compound feeds were mixed. Crude protein, calcium, phosphorus, amino acid were determined according to Chinese Technical Committee for Feed Industry Standardization and Chinese Association of Feed Industry (1996) and Chinese Quality Technical Superintend Bureau (2000), respectively. Formulas and nutrient levels are shown in Table 2.

Slaughter procedures

6 pigs (3, male, 3, female) were selected when the average body weight is near to 20 kg, 35 kg, 50 kg, 80 kg, 100 kg, respectively at each site. Pigs were transported to the slaughter plant where they had access to water and were slaughtered within 12 h after arrival. The pigs were weighed, stunned, and immediately exsanguinated. Using conventional methods according to General Department of National Standards (1982), pigs were scalded and dehaired. The head was removed at the atlas vertebra. All visceral organs, minus gastrointestinal contents, and leaf-fat were weighed. The carcass was split along the dorsal midline and weights of the two carcass halves were taken. The right carcass side was separated into lean (including intramuscular fat), skin-fat (skin and fat), and bone and weighed separately (Four students were in charge of different procedures in order to remove the variation caused by slaughtering process from different locations).

Sample collections

Lean and skin-fat from right side was chopped into small pieces in a commercial butcher's mincer and 2 kg sample was collected and frozen 20 h in freeze dryer (Dura-Dry^{TM} MP$^{[*]}$), respectively. Opened the samples to the air 12 hours and measured crude moisture percentage.

Carcass fat-free lean

Lipid percentage of lean and fat was determined

Table 1. Experimental designs and feeding managements of different sites

Site	North	Central	South	Southwest	Northeast
	Beijing	Wuhan	Guangzhou	Chongqing	Harbin
Pigs	48	60	54	48	48
Genetic	L×LW×BB [a]	D×L×LW [b]	D×L×LW [c]	L×R [d]	L×HW [e]
Replicates	12	12	6	6	6
House	insulated	semi-insulated	semi-insulated	insulated	insulated
Space	1.8×1.5 m^2	3.8×2.3 m^2	4.1×3.2 m^2	3.8×2.4 m^2	3.0×2.5 m^2
Floor	concrete	concrete	concrete	concrete	concrete
Drainage	well	well	well	well	well
Ventilation	well	well	well	well	well
Ingestion	*ad libitum*	*ad libitum*	*ad libitum*	*ad libitum*	*ad libitum*
Drinking water	*ad libitum*	*ad libitum*	*ad libitum*	*ad libitum*	*ad libitum*

[a] L×LW×BB=Landrace×Large White×Beijing Black; [b] D×L×LW=Duroc×Landrace×Large White; [c] D×L×LW=Duroc×Landrace×Large White; [d] L×R=Landrace×Rongchang; [e] L×HW=Landrace×Harbin White.

Table 2. Diet composition and nutrient level (air dry basis)

Ingredients, %	20 to 50 kg	50 to 80 kg	80 to 110 kg
Corn	61.70	69.53	76.74
Soybean meal	30.95	23.96	17.52
Soybean oil	4.16	3.57	3.00
Limestone	0.42	0.41	0.50
Dicalcium phosphate	1.17	0.92	0.70
Salt	0.34	0.34	0.34
Premix	1.00	1.00	1.00
L-lysine	0.26	0.27	0.20
Calculated diet composition			
Digestible energy (MJ/kg)	14.23	14.23	14.23
Crude protein%	17.9	15.6	13.3
L-lysine%	1.10	0.95	0.75
Calcium%	0.61	0.51	0.46
Phosphorus%	0.51	0.46	0.41
Methionine%	0.29	0.26	0.23
Methionine+Cysteine%	0.60	0.53	0.47
Threonine.%	0.75	0.63	0.53
Tryptophan%	0.25	0.21	0.17

a: The formula was uniform all over the country.

b: Crude protein, calcium, phosphorus, amino acid were determined in North (Beijing) experiment.

c: Premix provided per kg of complete diet: Iron, 100.0 mg; Zinc, 100.0 mg; Manganese, 10.0 mg; Copper, 10.0 mg; Selenium, 0.3 mg; Iodine, 0.5 mg; Vitamin A, 2,000 IU; Vitamin D_3 200 IU; Vitamin E, 20 IU; Vitamin K_3 0.50 mg; Biotin, 0.05 mg; Folic acid, 0.30 mg; Nicotinic acid, 20.0 mg; Pantothenic acid, 20.0 mg; Riboflavin, 2.5 mg; Thiamin, 2.0 mg; Pyridoxine, 1.0 mg; Cyanocobalamin, 10.0 ug; Choline Chloride, 1.0 g; Tylosin, 30.0 mg; Anti-oxidant, 200.0 mg.

according to AOAC (1995). Carcass fat-free lean was calculated as Fahey (1977) and Wagner (1999):

FFL=DL-DL×CL%/CLT%. where DL was dissected lean, CL% was the percentage of lipid in the dissected lean, and CLT%, was the lipid in the pooled dissected fat sample.

The method of calculating fat-free lean gain

Simulated carcass fat-free lean weight of growing-finishing pigs with different body weight. Predicted carcass fat-free lean weight when the body weight is 20 kg or 100 kg. Simulated the age of growing-finishing pigs with different body weight. Predicted the feeding days from 20 kg to 100 kg body weight. Calculate carcass fat-free lean gain as formula below:

Carcass fat-free lean gain
=(Carcass fat-free lean weight with 100 kg body weight-Carcass fat-free lean weight with 20 kg body weight)/ Feeding days

Statistical analysis

All data were analyzed by SPSS 9.0. Least square means were calculated with the GLM procedure for each weight group with the ANOVA model consisting of weight group, genetic population, sex, and their interactions.

Fitted the feeding days (Y, day) and carcass fat-free lean weight (Y, kg) to live weight (X, kg) by allometric function. $Y=b_0X^{b1}$. by which we can get predicted feeding days and fat-free lean weight when the live weight is 20 and 100 kg respectively.

RESULTS

Carcass composition

Carcass dissected lean weights, lean lipids and carcass fat-free lean weights were characterized in Table 3 and Figure 1, 2, 3. The effects of weight group, genetic population and weight group × genetic population were significant ($p<0.01$). The effects of sex, and weight group×sex were not significant ($p>0.05$). In the same weight group, dissected carcass lean were not significant between different genetics and sex. There is no interaction effect between genetics and sex. Lean lipids were significant ($p<0.05$) between different genetically hogs. Dissected carcass lean weights increased as body weight increased and are not significant ($p>0.05$) between barrows and gilts at most of weight groups. Also lean lipids increased as body weight increased and are not significant ($p>0.05$) between barrows and gilts at most of weight groups.

Carcass fat-free lean weights were not significant ($p>0.05$) between barrows and gilts. Carcass fat-free lean weights increased as live weight increased. The diversity of carcass fat-free lean weights of different genetically hogs was not large.

Fat-free lean gain

As shown in Table 4, and Table 5, allometric function. $Y=b_0X^{b1}$ simulated well the changes of growth days and carcass fat-free lean weights as live weight increased.

Carcass fat-free lean gain (shown in Table 6) of Duroc×Landrace×Large White, average, 311 g/d, was highest among different genetic hogs. Next was Landrace× Large White×Beijing Black, Duroc×Large White×Landrace, Landrace×Harbin White, and Landrace×Rongchang, carcass fat-free lean gain, at 261 g/d, 259 g/d, 220 g/d, 200 g/d, respectively. The inherent cause of the difference of carcass fat-free lean gain may be different genetic potential, feeding management and environment.

DISCUSSION

In China, there are more than 60 genotypes of pigs. But on most of pig farms, the genotype of pigs are Duroc×Landrace×Large White, Duroc×Large White× Landrace or local breed crossed with foreign breed. In this study, the genetic background of pigs was not investigated. And in fact, it was very difficult to investigate in detail. We

Table 3. Mass of dissected carcass lean, lean lipids, and fat-free lean (kg)

Weight group, kg	Genetic population	Dissected carcass lean, kg		Lean lipid, kg		Carcass fat-free lean, kg	
		Barrows	Gilts	Barrows	Gilts	Barrows	Gilts
20	Mean	8.0	8.1	0.7	0.6	7.2	7.3
	L×LW×BB	8.7	7.7	0.6	0.5	7.8	6.9
	D×L×LW	7.4	7.8	1.2	1.1	6.6	7.0
	D×LW×L	7.8	8.4	0.4	0.4	7.0	7.5
	L×R	6.6	7.1	0.8	0.8	5.9	6.4
	L×HW	9.4	9.5	0.4	0.3	8.5	8.6
35	Mean	14.0	14.0	1.0	1.0	12.6	12.6
	L×LW×BB	13.7	14.1	1.1	1.3	12.4	12.7
	D×L×LW	13.8	14.3	0.8	0.8	12.5	12.9
	D×LW×L	15.0	14.6	0.8	0.8	13.5	13.2
	L×R	13.2	12.6	1.3	1.2	11.9	11.3
	L×HW	14.0	14.2	1.0	0.9	12.6	12.8
50	Mean	22.1	21.6	2.0	1.6	19.9	19.4
	L×LW×BB	23.0	21.2	2.3	1.3	20.7	19.1
	D×L×LW	21.9	22.4	2.3	2.1	25.8	22.7
	D×LW×L	28.7	25.3	1.3	1.4	19.7	20.1
	L×R	17.3	18.7	2.1	2.1	15.6	16.8
	L×HW	19.7	20.4	1.9	1.2	17.7	18.3
80	Mean	33.2	33.0	3.7	3.8	29.8	29.7
	L×LW×BB	36.9	33.8	5.5	4.7	33.2	30.4
	D×L×LW	35.0	36.3	4.5	3.3	31.5	32.6
	D×LW×L	37.2	36.2	2.3	2.2	33.5	32.6
	L×R	24.7	24.4	4.2	6.2	22.2	22.0
	L×HW	32.0	34.5	2.3	3.0	28.8	31.0
100	Mean	39.6	39.5	4.66	4.86	35.6	35.5
	L×LW×BB	36.5	38.1	5.1	4.7	32.8	34.2
	D×L×LW	46.2	47.7	6.8	7.3	41.6	42.9
	D×LW×L	43.3	41.4	2.6	2.7	38.9	37.3
	L×R	31.9	32.4	5.4	5.6	28.7	29.2
	L×HW	37.8	41.1	3.4	4.0	34.1	37.0
Average SE		0.17		0.06		0.16	
Effects[a]		W***, G***, W×G***, S, W×S		W***, G***, W×G***, S, W×S		W***, G***, W×G***, S, W×S	

[a] W=Weight group; S=Sex; G=Genetic population; W×G=Weight group by genetic population interaction; W×S=Weight group by sex interaction; * p<0.05. ** p<0.01. *** p<0.001.

selected typical genotype, typical farm in the experimental region. We hoped that represented swine production of China.

In General Department of National Standards (1987), digestible energy density, crude protein and total lysine level are 12.97 MJ/kg, 16% and 0.75% when the body weight of pigs is from 20-60 kg, 12.97 MJ/kg, 14% and 0.63%, from 60-90 kg, respectively. In NRC (1998), digestible energy density, crude protein and total lysine level are 14.23 MJ/kg, 18% and 0.95% when the body weight of pig is from 20-50 kg, 14.23 MJ/kg, 15.5% and 0.75%, from 50-80 kg, 14.23 MJ/kg, 13.2% and 0.60%, from 80-120 kg, respectively. In this experiment, nutritional level is higher than General Department of National Standards (1987) and NRC (1998). Therefore, we thought the nutritional level is almost sufficient and would not limit the growth potential of growing-finishing pigs.

Carcass dissection procedure in this study differ from NPPC (2000), in which loin, ham, and Boston butt are dissected respectively. And sample collections are the same as Bikker et al. (1994), who cut the right carcass into pieces and homogenized separately in a mincer. But the method differs from Tess et al. (1986), Schinckel et al. (1996), Gu et al. (1992) and Wagner et al. (1999), who ground all components of left side carcass. So it is difficult to compare some experimental results because the measurements represented different traits and were not consistent between different studies (Gu et al., 1992). For instance, empty body weight was determined either as live weight minus gut weight (Davies, 1974) or as live weight minus intestinal content weight (Shields et al., 1983; Tess et al., 1986). Carcass weight was defined as that with both head and feet attached (Davies, 1974), or rear legs adjoined but head removed (Shields et al., 1983).

Table 4. The simulated functions of growth age with different body weight

		df	b_0	b_1	R^2
L×LW×BB	Barrows	15	11.0704	0.5897	0.962
	Gilts	15	11.1231	0.5927	0.978
	Average	30	11.1022	0.5912	0.969
D×L×LW	Barrows	15	8.0734	0.6735	0.941
	Gilts	15	6.6131	0.7373	0.945
	Average	30	7.4193	0.7011	0.939
D×LW×L	Barrows	15	5.6849	0.7081	0.969
	Gilts	15	5.4979	0.7253	0.980
	Average	30	5.6147	0.7155	0.973
L×R	Barrows	15	8.1584	0.6549	0.974
	Gilts	15	8.4050	0.6512	0.969
	Average	30	8.2895	0.6528	0.971
L×HW	Barrows	15	7.9616	0.6986	0.960
	Gilts	15	8.0837	0.6923	0.969
	Average	30	8.0264	0.6953	0.965

Model: $Y=b_0X^{b_1}$, Y, Body weight (kg); X, Age, (day).

Table 5. Simulated functions of carcass fat-free lean weight with different body weight

		df	b_0	b_1	R^2
L×LW×BB	Barrows	15	0.3978	0.9736	0.949
	Gilts	15	0.4403	0.9425	0.975
	Average	30	0.4208	0.9567	0.962
D×L×LW	Barrows	15	0.2789	1.0685	0.992
	Gilts	15	0.2443	1.1184	0.988
	Average	30	0.2709	1.0830	0.988
D×L×LW	Barrows	15	0.2734	1.0771	0.993
	Gilts	15	0.2984	1.0612	0.995
	Average	30	0.2858	1.0691	0.993
L×R	Barrows	15	0.4014	0.9214	0.979
	Gilts	15	0.4339	0.9086	0.987
	Average	30	0.4174	0.9150	0.982
L×HW	Barrows	15	0.3493	0.9995	0.984
	Gilts	15	0.2997	1.0497	0.988
	Average	30	0.3233	1.0248	0.984

Model: $Y=b_0X^{b_1}$, Y, Fat-free lean weight (kg); X, Body weight (kg).

Bikker et al. (1996) determined protein and lipid accretion in body components of finishing gilts. Lean weights, lean lipids and fat-free lean weights are not significant between barrows and gilts at most of growth stages. It is different from Wagner et al. (1999), who concluded that differences (p<0.05) existed between barrows and gilts for nearly all components investigated. Carcass lean and fat tissues significantly increased in lipid percentage as live weight increased. There are significant changes in the ratio and composition of the tissues of barrows and gilts during growth. Nonlinear models fitted the data better than allometric equations for nearly all of the components investigated.

Shields et al. (1983) reported fat weight increased curvilinearly with increasing empty body weight: the rate of fat deposition increased faster during the latter growth stages while water had declining deposition rates. Gilts contained more water and less fat than barrows at similar slaughter weights. Wagner et al. (1995) thought difference (p<0.05) exited between barrows and gilts for the quantity of fat-free lean, fat in the carcass and lipid in the empty body. Augmented allometric function best describes carcass fat-free lean. Lean weight, lean lipids and fat-free lean weights increased almost linearly as live weight increased. It is the same as Gu et al. (1992), who reported growth of lean in the carcass were nearly linearly associated with increased in body weight. Perhaps, the reason is that the growth period of the hogs is from 20 kg to 90 kg. Generally, the hogs grow rapidly at low body weights, tends to plateau during the grower-finisher phase and declines to zero as the hog reach maturity.

Schinckel (1997), Wagner et al. (1999) thought allometric function have several advantages including 1) simple stable linear solutions after the log to log transformation, 2) straightforward biological interpretation, and 3) simple, stable derivatives. $dY/dX=bb_1X^{b-1}$. Evans and Kempster (1979) stated three objections to their use in relating body components to empty body mass or other part-to-whole relationships. 1) It may be inapplicable at the earliest and latest stages of growth. 2) If the growth of a body component over time fits a flexible inflection point sigmoid growth curve, then the relationship of the body component to body weight is not, in general, allometric from birth to maturity. 3) There are difficulties in using the allometric function in a multicomponent growth model. In this study, we did not observed these objections.

The nutrient requirements are determined by lean growth index and lean growth index is determined by genotype. Therefore, it is rather important to measure lean growth index and then nutrient requirements can be predicted. NPPC (1994) firstly established standard method to measure fat-free lean. NRC (1998) computer model predicted nutrient requirements by fat-free lean.

In the experiment, carcass fat-free lean gain was determined by dissecting carcass lean. The method was different from Schinckel et al. (1996) and Kim et al. (2000) who determined fat-free lean gain of growing-finishing pigs indirectly. Schinckel et al. (1996) estimated fat-free lean

Table 6. Carcass fat-free lean gain of different genetic pigs

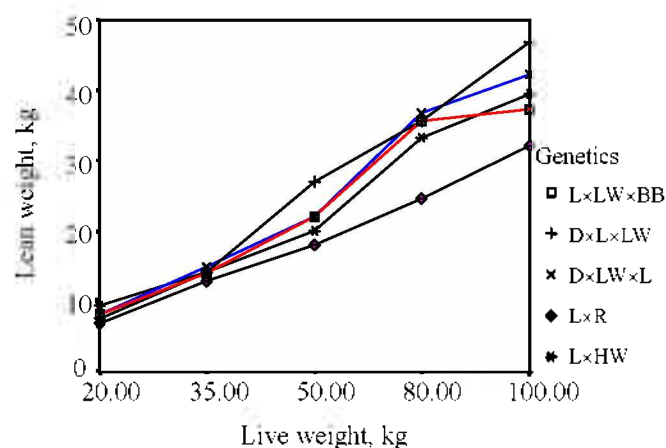|		L×LW×BB	D×L×LW	D×L×LW	L×R	L×HW
20-100 kg (g/d)	Barrows	272	264	319	199	208
	Gilts	252	257	303	200	233
	Average	261	259	311	200	220

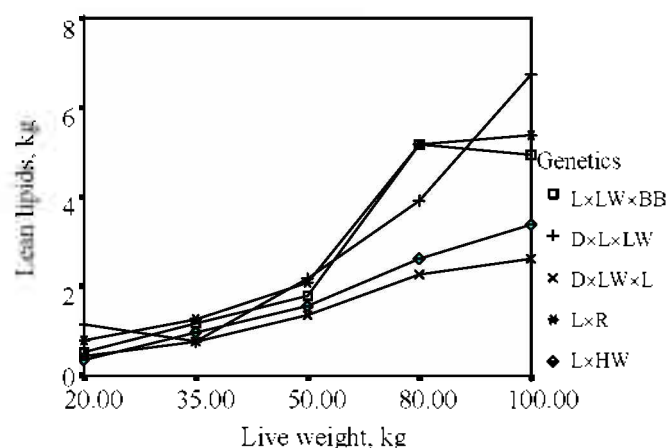**Figure 1.** Lean weight of different genetic pigs.

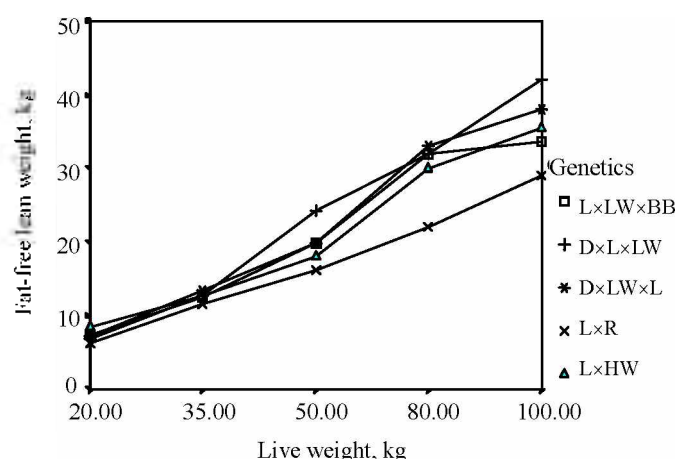**Figure 2.** Lean lipids of different genetic pigs.

Figure 3. Carcass fat-free lean weight of different genetic pigs

gain of pigs between 20 and 120 kilograms live weight. Average fat-free lean gain is 283 g/d. Kim et al. (2000)

calculated fat-free lean gain of 9.540 growing-finishing pigs by the equations suggested by NRC (1998). Fat-free lean gains of pigs with high, intermediate and low protein deposition rate are 355 g/d, 329 g/d and 303 g/d, respectively. Also, the data of carcass fat-free lean gain in the experiment were lower than intermediate fat-free lean gain (325 g/d) in NRC (1998). It indicated that lean growth rate of growing-finishing hogs was lower on commercial farm in China or the environmental condition limited the growth performance of the pigs.

ACKNOWLEDGEMENTS

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